CHAPTER

5 Magnetism and Matter

- A natural magnet is an ore of iron (Fe_3O_4) which attracts small pieces of iron, cobalt and nickel towards it.
- Lodestone is a natural magnet.
- Unit pole is defined as that pole which when placed in vacuum (or in air) at a distance of one meter from an equal and similar pole, repels it with a force equal to 10^{-7} newton.
- A current carrying loop behaves as a magnet i.e. magnetic dipole. Thus magnetic dipole moment of a current loop is. $M = IA$
  where, A= area of the loop.
- A current carrying straight solenoid behaves like a bar magnet.
- Angle of dip (δ): The angle formed by the total field vector with respect to horizontal plane is the angle of dip.

  $$\frac{B_V}{B_H} = \tan\delta$$

  B_H = horizontal component.
  B_V = vertical component of earth's field B.
  δ = Angle of dip.
- Angle of dip δ is zero at magnetic equator. Hence on magnetic equator, $B_H = B$, $B_V = 0$.
- Angle of dip δ is 90° at the poles. Hence at poles, $B_V = B$, $B_H = 0$.
- When the magnetic needle oscillates in the vertical east-west plane, at right angles to magnetic meridian, then only B_V acts on it.
- When the dip needle oscillates at right angles to the magnetic meridian in a horizontal plane, then only B_H acts on it.
- When the dip needle oscillates in the vertical plane in magnetic meridian, then both the components B_V and B_H of earth's magnetic field act upon it.
- The horizontal component of earth's magnetic field B_H acts from south to north direction.
- A line drawn through points of equal declination is called **isogonal line**.
- A line drawn through points of zero declination is called **agonal line**.
- A line passing through places of same value of dip is called **isoclinic line**.
- Isoclinic line corresponding to zero dip is called **aclinic line**, or **magnetic equator**.
- A line passing through places having equal values of B_H is called **isodynamic line**.
- **Vibration magnetometer** is used for comparing magnetic moments of two magnets and also for comparing the horizontal component of earth's field at two places.
- In a vibration magnetometer, the period of oscillation T is given by $T = 2\pi\sqrt{I / MB_H}$, where I is the moment of inertia of the magnet about the suspension.
- Frequency of oscillation in a vibration magnetometer is given by, $n = \frac{1}{2\pi}\sqrt{MB_H / I}$.
- If two magnets are placed one above the other symmetrically and allowed to oscillate with a period, T_1 in a horizontal plane with a uniform field and with a period T_2 when one of the magnets is reversed, then $\frac{M_1}{M_2} = \frac{T_2^2 + T_1^2}{T_2^2 - T_1^2}$, M_1 and M_2 being the moments of the magnets.

Magnetic quantities-Units and dimensions

S.No.	Quantity	S.I. Unit	Dimensions
1.	Magnetic moment (vector quantity), $\vec{M} = I\vec{A}, \vec{M} = m \times \vec{\ell}$	Am^2	L^2A^1
2.	Pole strength (scalar), $m = M/\ell$	Am	LA
3.	Intensity of magnetisation (vector) $\vec{I} = \vec{M} / V$	Am^{-1}	$L^{-1}A$
4.	Magnetic flux (Scalar) $\phi = \vec{B} \cdot \vec{A}$	weber	$ML^2T^{-2}A^{-1}$

5.	Magnetic induction (vector) $\vec{B}$	Wb m^{-2} or tesla Am^{-1}	$MT^{-2}A^{-1}$
6.	Intensity of magnetic field (vector)	Am^{-1}	$L^{-1}A$
7.	Magnetic permeability (scalar), $\mu = B/H$	H/m	$MLT^{-2}A^{-2}$
8.	Relative permeability (scalar), $\mu_r = \mu/\mu_0$	unitless	zero dimension
9.	Magnetic susceptibility (scalar) $\chi_m = I/H$, $\chi_m = (\mu_r - 1)$	unitless	zero dimension
10.	Periodic time of a magnet (scalar) $T = 2\pi\sqrt{\frac{I}{MB_H}}$ (I = moment of inertia)	sec	T

- **Electromagnets:** The material for cores of electromagnets should have maximum flux density with comparatively small magnetising field and low hysteresis loss. Soft iron is best suited for electromagnet. The hysteresis loop is thin and long. Due to the small area of hysteresis loop, energy loss is small.
- For soft iron retentivity/remanant magnetism is high, coercivity is low, magnetic permeability μ is high and magnetic susceptibility (χ_m) is high.
- For steel, remanant magnetism is low, coercivity is high, μ is low and χ_m is low.
- About 90% of magnetic moment is due to spin motion of electrons while remaining 10% is due to their orbital motion.
- Magnetic moment associated with an electron (or charge) having charge e when it revolves in a circular orbit of radius r with angular speed ω is

  $$M = \frac{e\omega r^2}{2} = \frac{er^2}{2} \times \frac{2\pi}{T} = \frac{er^2\pi}{T}$$

- The magnetic moment associated with the electron revolving in the first Bohr orbit is known as Bohr magneton (μ_B).

  $$\mu_B = \frac{eh}{4\pi m} = 0.93 \times 10^{-23}\ JT^{-1}$$

- All substances exhibit diamagnetism. In paramagnetic and ferromagnetic substances, the diamagnetism is neutralised by the large intrinsic dipole moment of spinning electrons.
- The apparent dip δ', the real dip δ and the angle with magnetic meridian θ are related as

  $\tan \delta \cos \theta = \tan \delta'$

- Magnetic length = $\frac{5}{6}$ × geometric length of magnet.